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Results of an analysis of response options in generation, demand and power trade for mitigating the impacts of intermittent RES-E supplies

Jacobsen, Henrik

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on

“Identification and analyses of market-based response options aimed at increasing the contribution of variable energy resources such as

Wind, photovoltaic and micro-CHP” in the electricity supply

Thursday 7 February, 2008

Henrik Klinge Jacobsen

Outline

- Impacts and major categories of response options
- Generation and demand response options
- How much impact on spot price? Example from DK
- Which options could mitigate the price variations and the price reduction?
- Reduction of variation in intermittent generation and possible price impacts
- Unpredictability of intermittent sources and gate closure time
- Are the illustrated impacts relevant in a broader EU perspective? – EU RES targets and the timing

Problems and Impacts
Focus on markets

- **Variability of intermittent sources - markets**
  - Price variation high
  - Low prices at times of high wind output
  - Low revenues for both intermittent generators and other base load generators

- **Unpredictability of intermittent sources**
  - High balancing costs
  - High and inflexible reserve requirements
  - Low capacity values

Different categories of options to mitigate the problem of price variations

Two major alternatives

- **Reduce the output variations**
  - Interconnection capacity
  - Flexible generation technologies in mix
  - Mix of intermittent generation technologies
  - Dispersed location of intermittent technologies

- **Demand options that soak up the output variations**
  - Increase price flexibility – demand response (regulation, technology)
  - Storage of electricity or heat
  - New demand technologies (heat pumps, hybrid electric cars)

Gross list of response options – examples

GENERATION	DEMAND	TRADE	TSOs and DSOs
Conventional units : Gas turbine (GT) single cycle Gas turbine combined cycle (CCGT) Gas engine Hydro power plant (PP) **Conventional units, base load :** Steam turbine (pulverized coal) Steam turbine (biomass) Waste CHP plant **Advanced technologies :** Micro-CHP (Fuel cells, Gas turbines, Gas engines, Diesel engines, Stirling engines) Fuel Cells (SOFC, PEMFC) Photovoltaic (PV) Wave power converters **Heat Production :** Heat pumps District heating boiler (biomass) DH boiler (oil, gas) Electric boiler **Modular systems :**	**Demand response :** Time of use tariffs Pricing based on spot market (day ahead) for large consumers Real time pricing (all price elements included) – general metering Peak pricing Automatic load control (frequency controlled appliances) Interruptible contracts **Energy conservation (DSM) :** Electricity saving investment programmes (subsidies) for peak shaving	**Electricity storage systems :** Batteries (Vanadium redox-flow, Regenesys, Zinc-Bromide, Lead-acid, Sodium-Sulphur, Nickel-Cadmium, Nickel-Hydride, Lithium-Ion, Polymer, Metal-air (Zn, Al, Mg) Compressed air energy systems (CAES) Super magnetic energy storage (SMES) Hydrogen-Fuel cell storage system (HFCSS) Supercapacitors Pumped hydro storage Hydropower reservoirs extension Flywheels **Heat storage** Short-term heat storage (steel water tank) Long-term (seasonal) heat storage (e.g. water pit storage) **Other types of storage :** Storage of electricity intensive intermediate products in industry Pumping and storing water in the water towers	***TSOs response options:*** **A renewable energy control centre:** Determine the RES-E and DG limitations to reduce the necessary reserves. ▪Identify the wind power production compatible to the interconnected power system security and the admissible voltage drops in the system. Measurement in real time. Aggregation of power plants. **▪Development of prediction tools** o**Technical adaptation:** oVoltage dips oFrecuency variations oImplementation of automatic intertripping of conventional units to compensate an increase of unpredictable production.

Generation technologies

- **Flexible generation technologies**
  - **Low stop and start costs as well as fast regulation properties**
  - **Reasonable part load characteristics – efficiency, emissions**

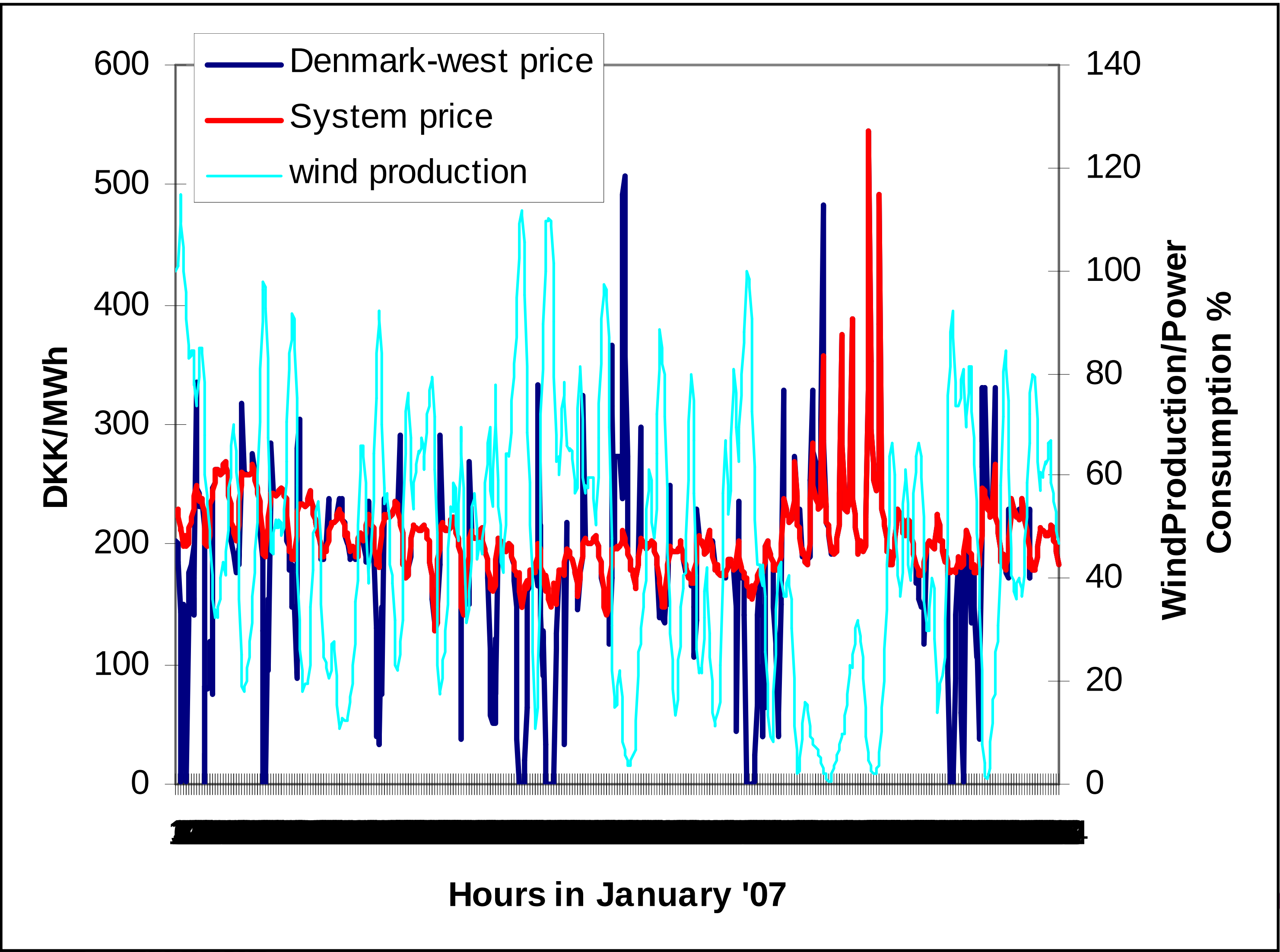
- **PV and wind power combination**
  - **Somewhat uncorrelated but dominated by cost differential**

- **Wind power and CHP**
  - **CHP can only be flexible with storage and correct subsidy scheme**
- **PV or Wind and Hydro**
  - **Excellent combination**

Demand options

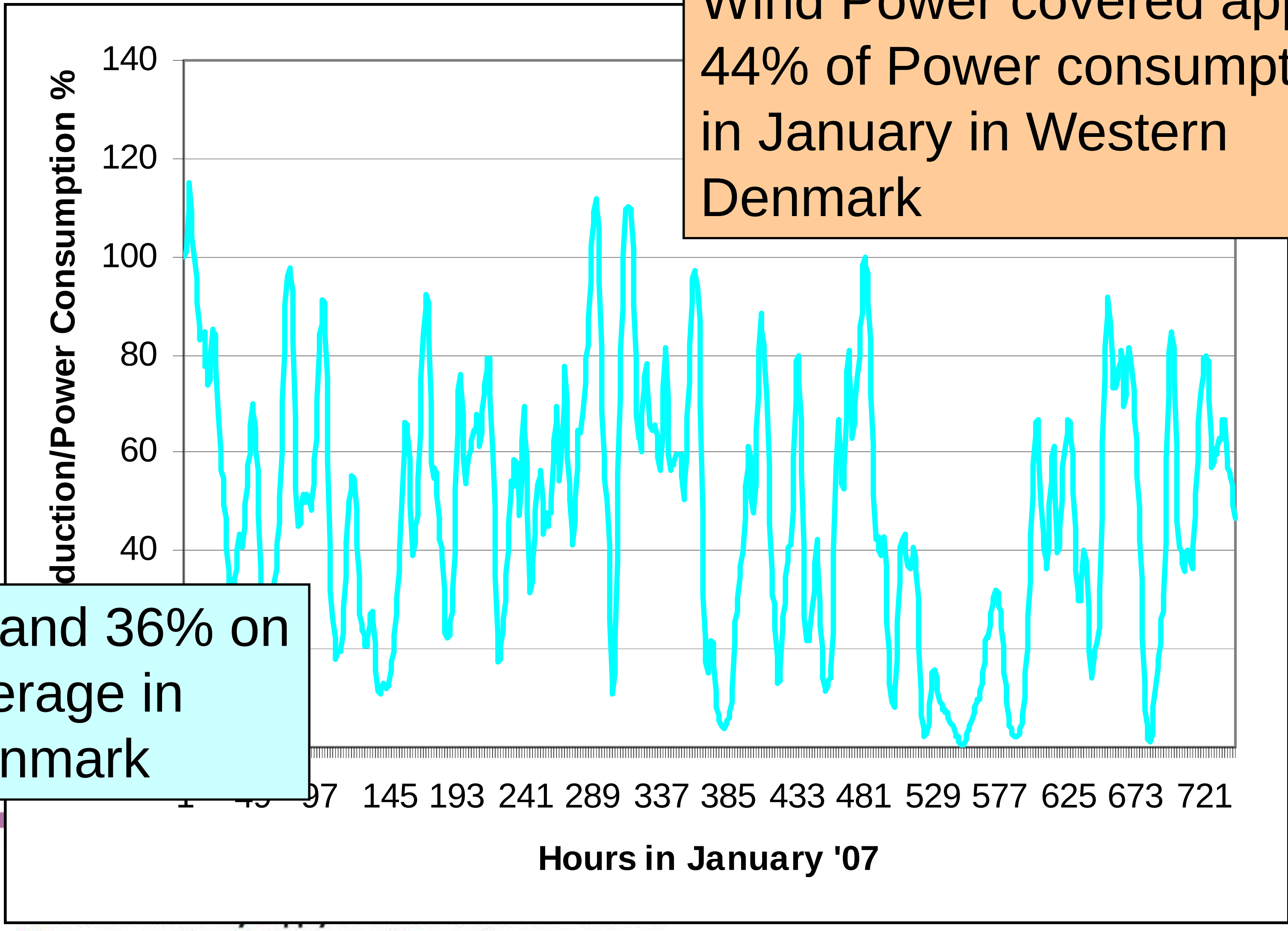
- **Demand options that shift demand or use the output variations**
  - **Metering**
    - **and billing that transfer the price signals to final consumers**
  - **Tariff restructuring**
    - **increase fluctuations that consider variations in environmental tax elements – including the PSO tariff that finance RES subsidies**
  - **New demand technologies (heat pumps, hybrid electric cars)**

Impact on Spot Price



Source: Poul Erik Morthorst

Wind power in Western Denmark



Wind Power covered approx. 44% of Power consumption in January in Western Denmark

… and 36% on average in Denmark

Source: Poul Erik Morthorst

Example of possible options to reduce price impact in Denmark

- **Example based on Poul Erik Morthorst calculation of West Denmark price impact**

- **This is a calculation to quantify the spot market price impact of having wind generation relative to no wind**

- **assuming that all other capacity is constant = no long term calculation**

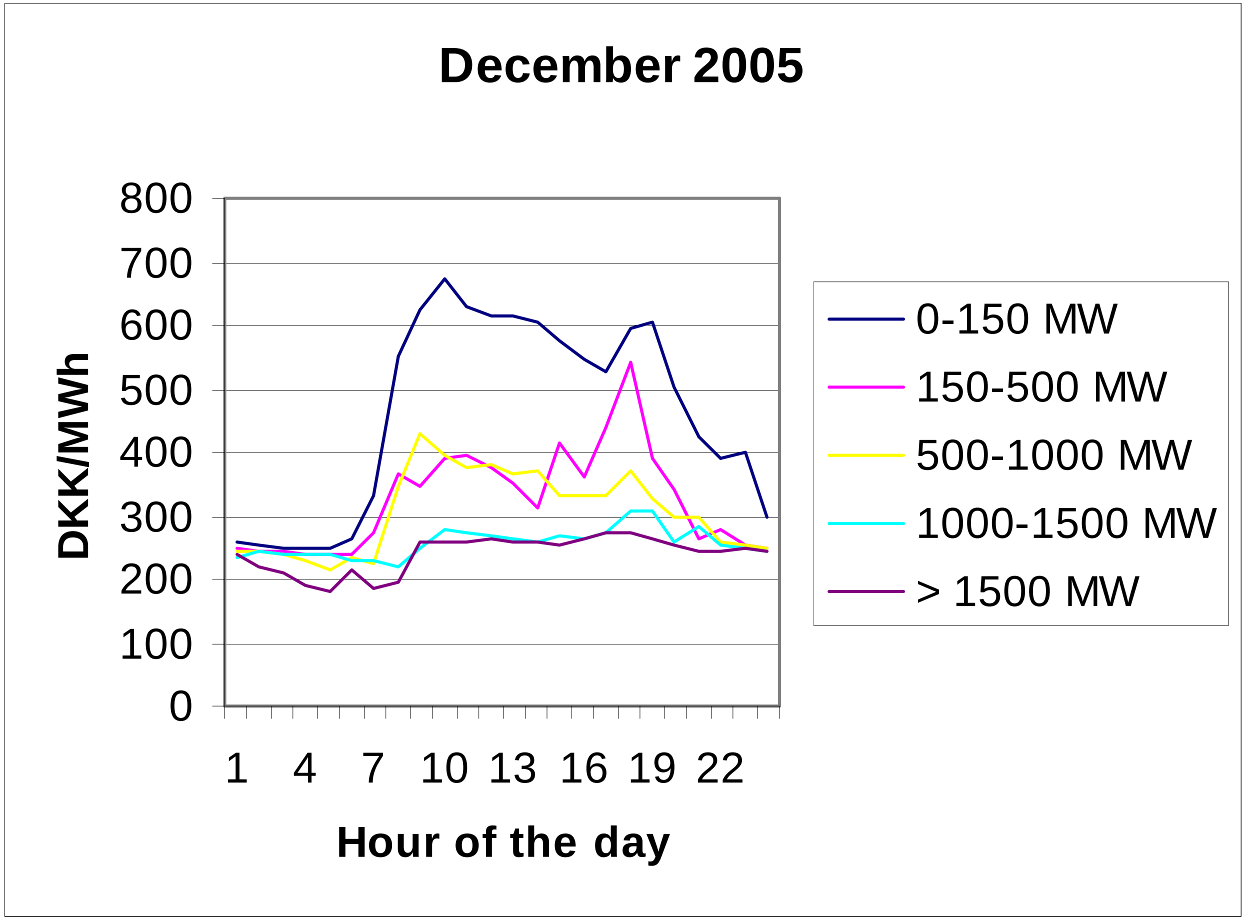
Decomposing – structural analysis

Calculations performed for

- Hour of the day (24 steps)
- Month of the year (max. 12 steps)
  - comparable month are merged
- Five categories of wind power
  - 0 – 150 MW equals ”No wind” reference
  - four more categories from ”low wind” to ”storm”, the lastmentioned covers more than 1500 MW

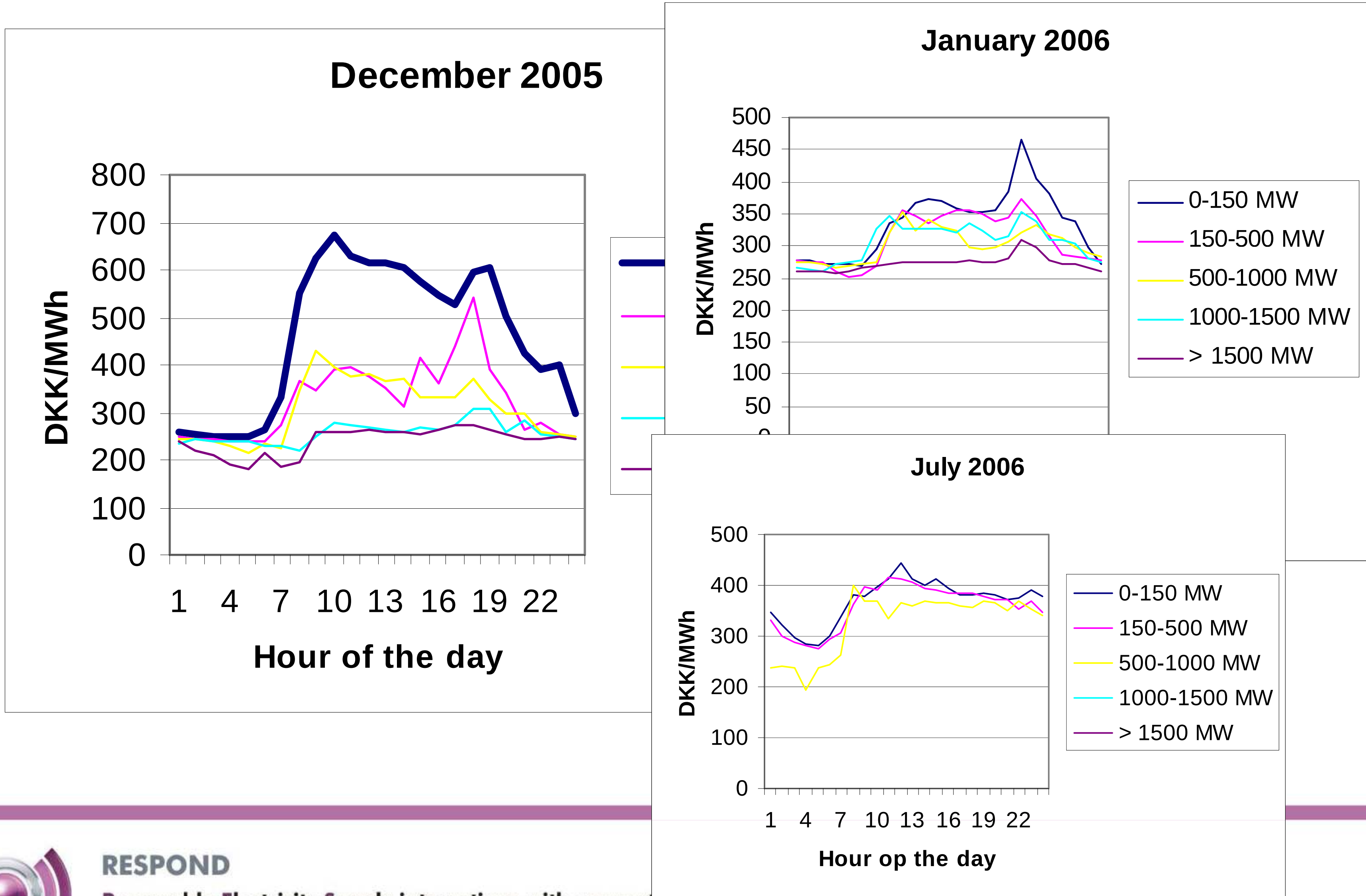
Source: Poul Erik Morthorst

Impact at the Western-Denmark power market



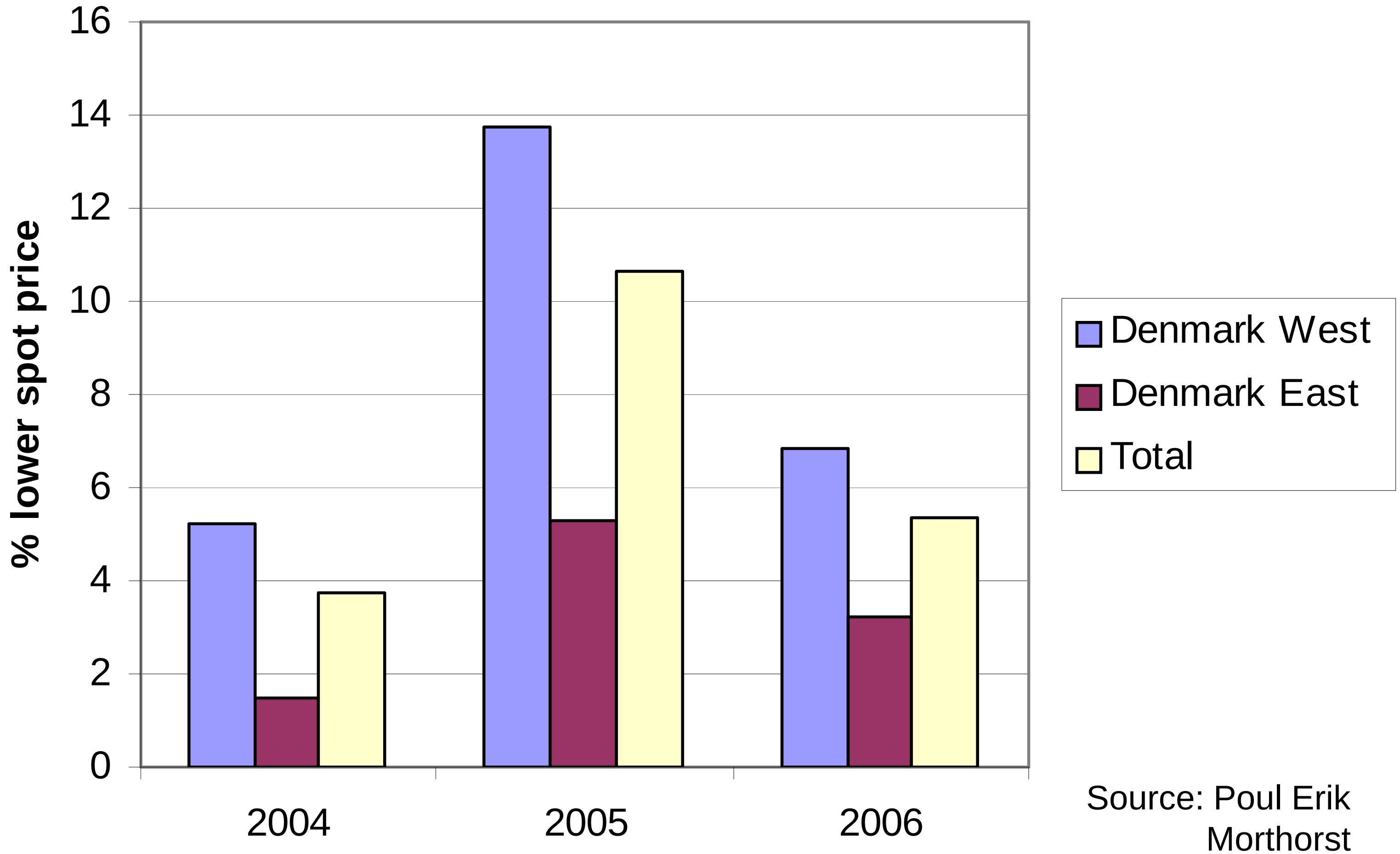
Source: Poul Erik Morthorst

Not so much impact in Summertime....



Source: Poul Erik Morthorst

Lower spot market prices: results for 3 years



Source: Poul Erik Morthorst

Interconnections, storage and demand response

- Interconnection capacity
  - Reduce the impact of variability on prices
  - Reduce the reserve requirement

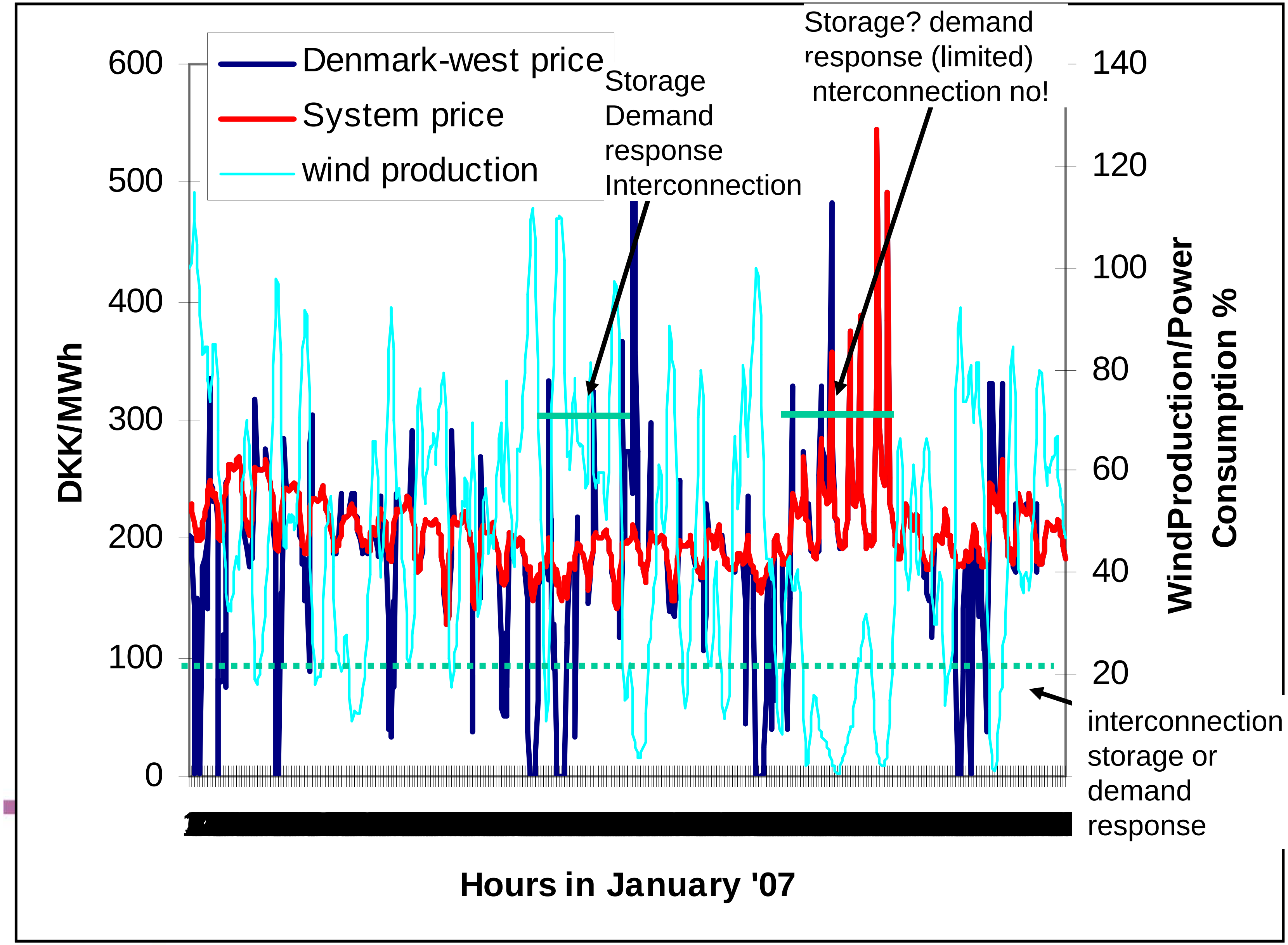
- Storage technologies
  - Use the variability of prices to store electricity or heat related to CHP – mainly short term
  - Hydro storage – both in short term and for longer term storage

- Demand response
  - Reduce variation of prices – flattened duration curve
  - Regulatory part
  - Technological part

Example of price impact reduction in a system with high intermittent shares and interconnection constraints

- **Why is the low prices a problem?**
- **In a system with high intermittent shares there are unattractive low prices – from the generators view**
- **There is a lot of short term price variation**
- **There might be longer periods of high prices**
- **And the average spot market price is lower**
- **Especially wind generators will experience low prices**

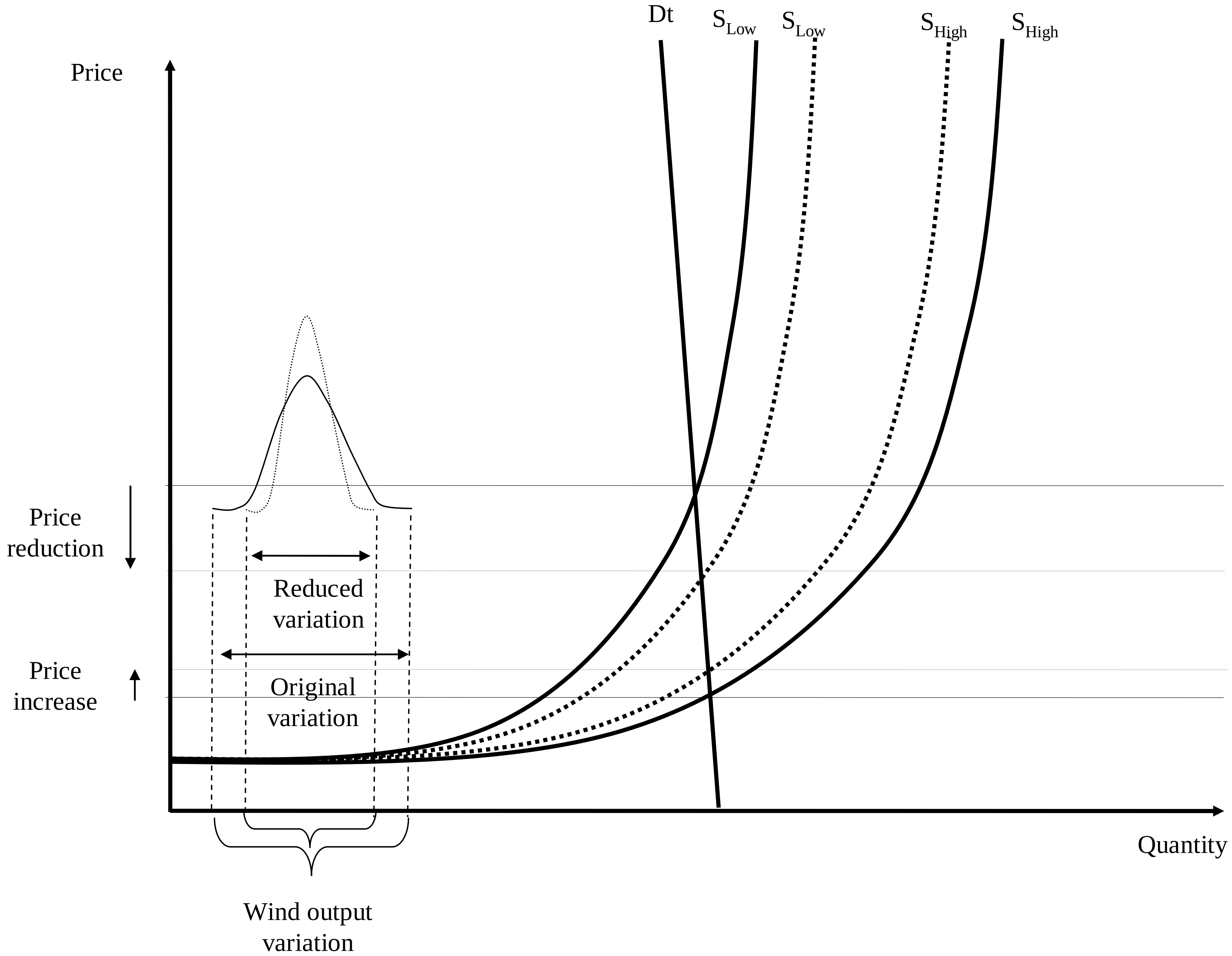
Demand response, storage or interconnection



What will the impact of reduced variation in generation be?

- For the options targeting a reduction of variability the main efficiency argument will be related to less capacity requirements and better average fuel efficiency in the long term
- But what about the short term effect for the market?

- Assume that less variability will reduce the max intermittent output and increase the minimum output identically
  - Lower max will increase prices
  - Higher minimum will reduce prices
  - What is the net effect and the distribution?



Dt
S_{Low}
S_{Low}
S_{High}
S_{High}
Price
Price reduction
Reduced variation
Original variation
Price increase
Quantity
Wind output variation

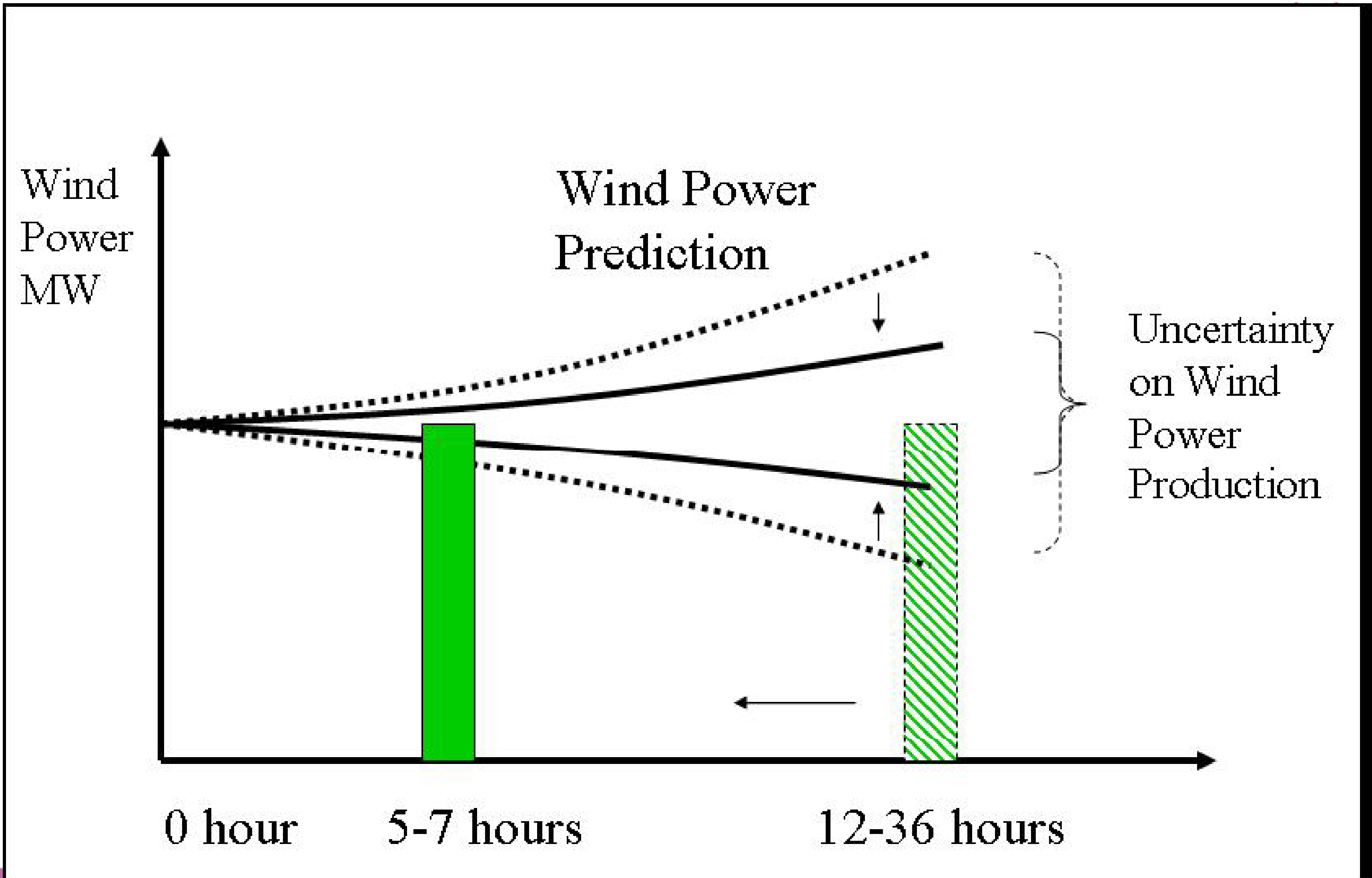
Prices will tend to be reduced more than they are increased

- For the average generator this is not attractive
- For the peak plants this is even less attractive
- But for wind generators this might even be a positive impact as they have high output at times of low prices and low output at times of high prices
- Therefore less variation might even increase the market part of their revenue in combination with better capacity value characteristics

Impacts of unpredictability and options

- Gate closure time:
- Markets are mostly organised with 12-36 hours ahead
- A reduction would benefit the need for balancing of wind
- Balancing cost could therefore be reduced

Gate closure time



The relationship between uncertainty on wind power production and gate closure time.

Impacts on prices of reduced gate closure time?

- Less overshooting projected intermittent generation – correct higher estimate reduce day ahead prices

- Less undershooting projected intermittent generation – correct lower estimate increase day ahead prices

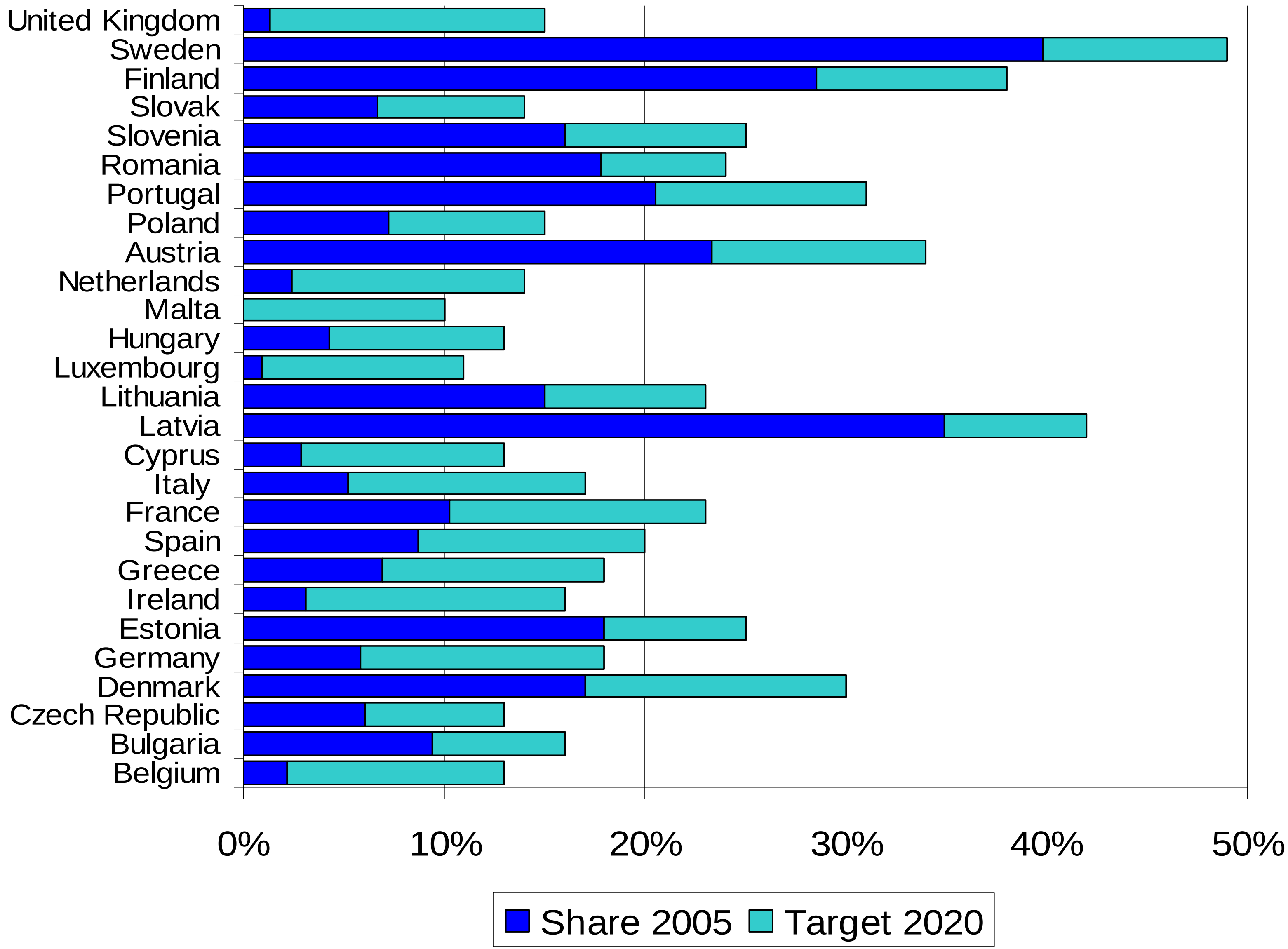
- It is not clear what the net effect on prices will be

- However intermittent generators will have lower balancing costs and therefore it will probably benefit them

Are the impacts and the options illustrated relevant?

- RES intermittent generation shares are only high in a few countries?
- But already at low shares networks will experience the impacts
- If EU targets are becoming reality the illustrated example might become the average rather than just a Danish extreme
- Therefore identifying a mix of options to mitigate the intermittent effects is vital to have a smooth implementation of the RES targets

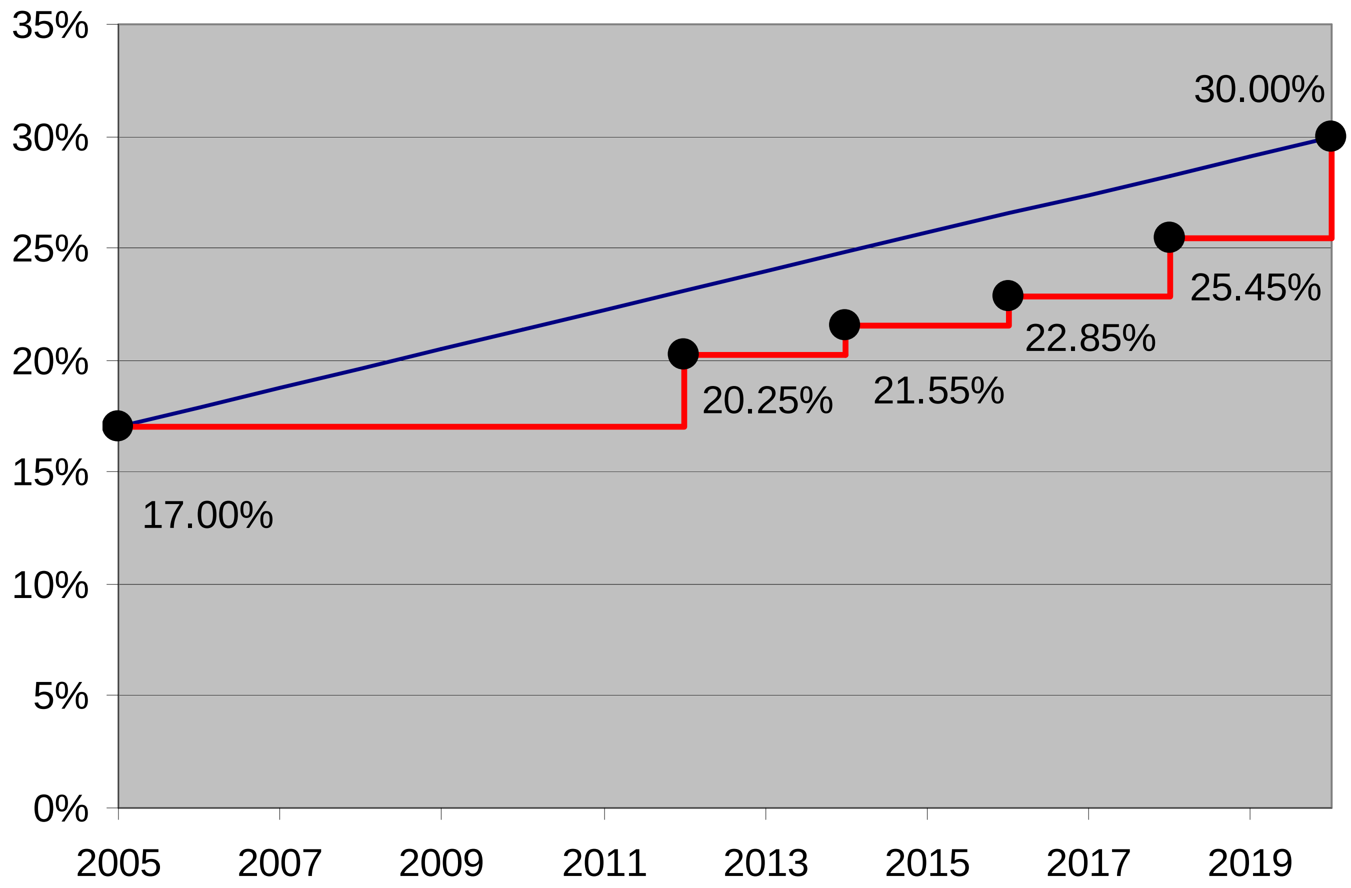
National RE Targets



Timing and options

- First we cannot wait to implement options to 2020 as interim targets are binding
- Different response options are relevant at different time horizons
- Targets are gradually increased up to 2020 – so we must make sure that options implemented in 2015 don't interferes with options planned to be in effect later on.
  - if we build interconnection
  - low prices during night-time to be exploited by hybrid (electric) vehicles will not be available (DK case)

Interim Target DK



Concluding remarks

- **New EU Directive including RES targets will increase the impacts that must be addressed due to high targets**
- **Market price effects of intermittent energy will be large**
- **A larger share of RES generation will be market based**
- **Variability in intermittent generation could be matched by flexible units in generation mix and cheap storage technologies**
- **Interconnection and demand response are important options**